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COMPARATIVE STUDY FOR ESTIMATION OF DYNAMIC STRESS AND STRAIN LEVELS INDUCED BY BLASTING VIBRATIONS

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This study investigates the truthfulness of the claims of damage of the buildings in the City of the 15th of May due to blasting vibrations. A comparative study has been carried out for three case studies: Golden Sunlight surface mine in Montana, Canada; Bani Khalid quarry, Samalout, Minia, and the limestone quarry of the National Cement Company in relation to the city of the 15th of May, Helwan, Egypt. As a result of the study, the magnitudes of the dynamic Young's modulus, strains, and stresses have been found compatible for Golden Sunlight mine and Bani Khalild case studies. On the other hand, the case of the city of the 15th of May has showed very high magnitudes for both dynamic Young's modulus and stresses. Hence, re-calculation and re-evaluation have been carried out following the procedures of Golden Sunlight mine and Bani Khalid cases. The obtained new magnitudes of Young's modulus and stresses are found compatible with Golden Sunlight and Bani Khalid. Accordingly, the conclusions of the previous study on the City of the 15th of May that damages of the buildings in the City are due to blasting vibrations are not acceptable. Re-investigation of the damage in the buildings of the city has to be carried out to find other causes of the damage. These causes may be geological, environmental or even design causes.

KEYWORDS: *Ground vibrations, seismic waves, dynamic elastic constants, dynamic stress and strain, Bani Khalid, and the city of The 15th of May.*

INTRODUCTION

Estimation of the level of the dynamic strains and stresses induced by ground vibrations due to blasting operations in mines and quarries is of concern to the mining, civil, and geological engineers. The reason is that these strains and stresses may cause damage to mining structures such as high walls and mine openings or nearby structures such as dwelling buildings, bridges, dams, tunnels, pipelines, and underground power stations. To estimate these dynamic strains and stresses, bulk density, dynamic elastic constants and/or seismic wave velocities should be available. Measurements of the ground peak particle velocities at the locations of interest should be available as well [1-5].

The elastic properties of rock materials are either evaluated from the conventional geotechnical methods or the in-situ geophysical measurements. Shallow geophysical techniques are considered as one of the accurate and cost effective methods used in engineering site characterization of the rock mass. They are an alternative means of the conventional geotechnical ones, which are sometimes tedious and very expensive [6,7]. The kinetic elastic moduli of the surface and shallow layers can be identified using the compression and shear waves velocities and the material bulk densities as well. The rock mass quality depends mainly upon the material elastic moduli, which include shear modulus, Poisson's ratio and Young's modulus [2, 4-13].

Helwan is a major industrial area in Egypt. Not only it is crowded with industries but also it is crowded with people. The area is under heavy demands from both of the industries and from the population. For example, there are three cement manufacturing companies in the area: Tora Cement Company; National Cement Company and Helwan Cement Company. All of the three companies are increasing their production to fulfill the national and international demand for cement. This increase in cement production needs increasing the production of limestone, the main raw material of this industry. Consequently, the number of blasts and the used quantities of explosives will increase. Tora Cement Company as an example has increased the number of blasts from 152 in year 1980 to 777 blasts in year 1990 [14]. The city of the 15th of May has been built to the north of Helwan. Now we are confronting the problem of urban expansion and the increase of quarrying activities at the same time and place. This means that the distances between urban areas and the quarries are getting closer and closer, increasing the sensitivity to and fear from blasting vibrations. Resident complaints against quarry managers and confrontations with them will increase and become more serious [12, 13, 15]. This calls for more scientific research to both understand the phenomena and suggest techniques to solve the anticipated problems.

AIM OF THE RESEARCH

The importance of the investigation of the dynamic strains and stresses induced by blasting vibrations has been high lighted in the introduction. In respond to the demand for research, the author is carrying out a comparative study for three case studies: Golden Sunlight surface mine in Montana, Canada; Bani Khalid quarry, Samalout, Minia, and the limestone quarry of the National Cement Company in relation to the city of the 15th of May, Helwan, Egypt. That is to investigate the truthfulness of the claims of damage of the buildings in the City of the 15th of May due to blasting vibrations.

STRESS AND STRAIN CALCULATION

In the near field of a detonating blast hole, the wave front is curved and the calculation of the stresses and strains is complicated. In the far field (at distances greater than 15 meter from the blast hole), the wave front can be considered planar (i.e. particles move parallel to the direction of propagation of the longitudinal wave). Also the wave is assumed to be sine wave. These assumptions simplify the method of calculation and these calculations are accurate enough for engineering applications. Dowding explains the method of calculation of strain and stress as follows [2]:

Compressive Stresses and Strains:

$$C_p = (E / \rho)^{1/2} \quad (1)$$

$$\varepsilon = \mathring{u} / -C_p \quad (2)$$

$$\sigma = \rho\, C_p\, \mathring{u} \quad (3)$$

$$E = \sigma / \varepsilon \quad (4)$$

Where:

ε = strain
σ =stress
$\mathring{u}$ = longitudinal particle velocity
ρ = mass density of rock
E = modulus of elasticity
C_p = longitudinal wave velocity.

Shear Stresses and Strains:

$$C_s = (G / \rho)^{1/2} \quad (5)$$

$$\gamma = \mathring{u}_s / -C_s \quad (6)$$

$$\tau = \rho\, C_s\, \mathring{u}_s \quad (7)$$

$$G = \tau / \gamma \quad (8)$$

Where:

γ = shear strain
τ = shear stress
$\mathring{u}_s$ = transverse (shear) particle velocity
C_s = shear wave velocity
ρ = mass density of rock
G = modulus of rigidity

The longitudinal and shear wave propagation velocities (in three dimensions) are related to the elastic constants by the following equations [8,9]:

$$(C_p)^2 = (1 - \upsilon)\, E / [(1 + \upsilon)\,(1 - 2\,\upsilon)\,\rho] \quad (9)$$

While:

$$(C_s)^2 = E / [2\,(1+ \upsilon)\,\rho] \quad (10)$$

With some manipulation between equations (9) and (10), we can find the following equation for calculating Poisson's Ratio, υ:

$$\upsilon = [1- 2\,(C_s / C_p)^2] / [2 - 2\,(C_s / C_p)^2] \quad (11)$$

And

$$C_p / C_s = [(1- \upsilon)/(1/2 - \upsilon)]^{1/2} \quad (12)$$

In case of υ =0.25, the C_p / C_s ratio is equal to 1.7.

CASE STUDY I: Golden Sunlight Mine, Montana, British Colombia, Canada

The study aimed at maintaining high wall stability and integrity in the Golden Sunlight mine in Montana. Burgher [11] has measured longitudinal and shear wave velocities directly using a special setup of Instantel DS-200, Instantel DS-500 seismographs and Instantel-DS-10 fiber optic system. In addition, he has measured the peak ground particle velocities resulting from blasting operations in the mine. From these measurements, he has calculated the stresses and strains following Dowding's procedure. He used equations (2) and (3) for calculating normal strains and stresses while equations (6) and (7) were used for shear strains and stresses. After changing the units from the English to the Metric system, we have summarized his results in **Table 1**

Table 1: Summary of results of Golden Sunlight mine obtained by Burgher [11]

Sp. Gr.	C_p, m/sec	C_s, m/sec	Dist., m	$\mathring{u}$, mm/sec	$\mathring{u}_s$, mm/sec	σ, kg/cm^2	ε, 10^{-6}	τ, kg/cm^2	γ, 10^{-6}
2.61	2486.6	1463.4	140.2	254	254	16.33	102	9.52	173

CASE STUDY II: BANI KHALID QUARRY, Samalout, Minia, Egypt

Bani Khalid quarry is situated on the eastern bank of the River Nile (100-500 m inward), four kilometers south east of Samalout town, Minia. It is the main source of limestone for the Egyptian Iron and Steel Company. It is about 190 kilometers south of the Iron and Steel Company in Helwan. Bani Khalid Village lies on the northern border of the quarry while Dier Gebel-Eltair Village lies on the southern border (**Figure 1**). The numulitic limestone of the quarry belongs to the middle Eocene. The productive limestone layers are geologically divided into four layers. From top down, layers I and II have a volumetric weight of 2t/m^3 and their thickness ranges from 0-21 m; followed by layers III and IV, which have a volumetric weight of 2.2 t/m^3 and thickness of about 15 m. On the top, small thickness (0-1.5 m) of loose overburden has a volumetric weight of 1.8t/m^3. The absolute ground water level is at 31 m (the level of the quarry bottom). The compressive strength of the quarry limestone ranges from 170-600 kg/cm^2 [4, 16].

Bani Khalid quarry have two benches. The height of the lower bench is about 10 m while the height of the upper bench varies from 6 to 20 m depending on the topography. Abdel-Rasoul and Omran [4] have carried out a shallow seismic refraction survey at the area between the upper quarry face and the northern borders of Dier Gebel-Eltair Village. The results of their interpretations revealed two bedding planes separating three layers. Also, they measured the ground peak particle velocities (PPV) produced by the blasting operations in the quarry near the foundations of the buildings of the northern border of Dier Gebel-Eltair Village. The distance between the recording stations and the center of the blasts ranged from 189 to 311 m. They have determined the seismic wave velocities; dynamic elastic constants; normal and shear strains; normal and shear stresses for the three layers. In estimating strains and stresses, they followed the procedure of Dowding [2]. They have carried out the calculations for the three layers using maximum and minimum magnitudes of the seismic velocities. Also, they used the maximum and minimum magnitudes of the PPV from blasts at the two benches. Summary of their results is provided in **Tables 2** and **3**.

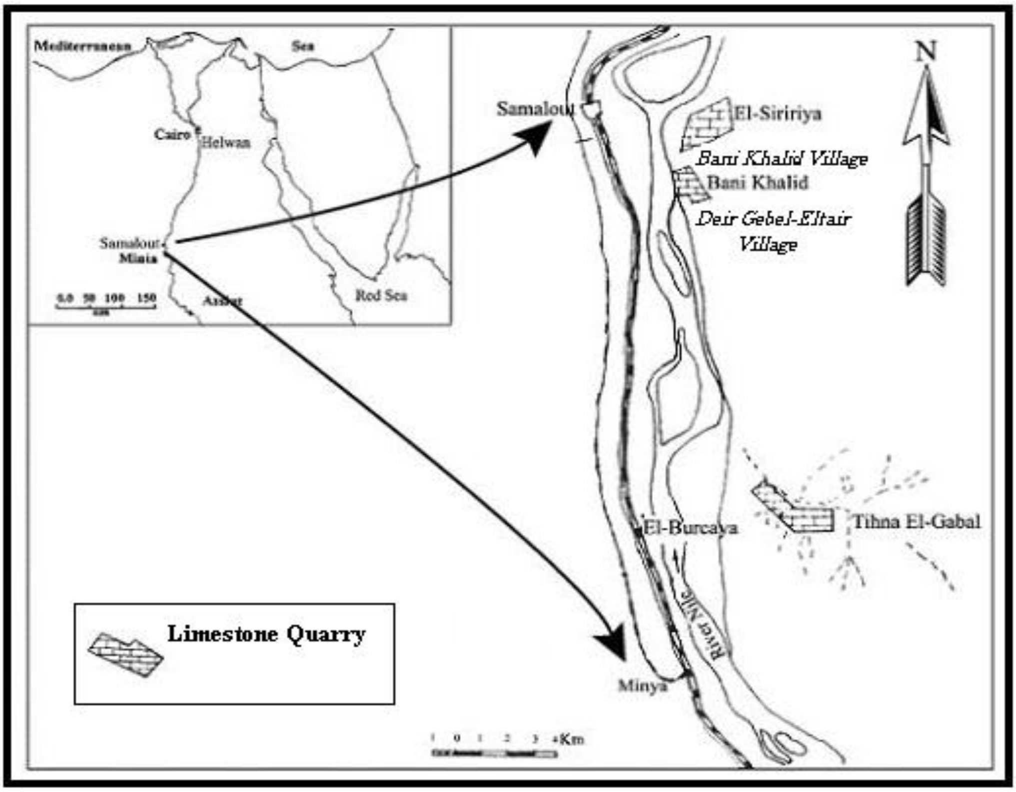

Fig. 1: Key map for Bani Khalid quarry [4].

Table 2: Summary of the calculations of the field dynamic Young's modulus (E), Bani Khalid quarry [4].

Layer 1		Layer 2		Layer 3	
Poisson's Ratio, υ	Young's Modulus, E, 10^4 kg/cm^2	Poisson's Ratio, υ	Young's Modulus, E, 10^4 kg/cm^2	Poisson's Ratio, υ	Young's Modulus, E, 10^4 kg/cm^2
0.18	5.18013	0.212	16.0020	0.094	46.6125
0.178	4.88926	0.104	13.4599	0.0935	42.1931

CASE STUDY III: The City of the 15th of May, Helwan, Egypt

Tealeb et al [12, 13, 15] have carried out an intensive monitoring of blasting ground vibrations and records have been collected during a long period (1997-2002), to estimate the dynamic stresses induced by ground vibrations of the blasts in the limestone quarries of the National Cement Company nearby the 15^{th} of May City, Helwan, Egypt. **Fig. 2** shows a location map for the city of the 15^{th} of May and the nearby quarry including a sketch for the observation points.

The 15^{th} of May community lies in the northern side of Helwan and it represents the northern extension of Helwan buildings. It is built on a rocky low land or platform of the Middle and Upper Eocene rocks. These rocks belong to Gebel El-Mokkattam that represents a hill bordering the eastern part of Cairo. The lower Mokkattam section (Middle Eocene) forms the area to the south of Gebel El-Mokkattam in the eastern cliffs of Helwan. It consists of white limestone. On the other hand, Upper Mokkattam section belongs to Upper Eocene and consists of red brown limestone. Wadi El-Gibbu and Wadi Garawi belong to the upper Mokkattam section. They are the main source of the quarriable limestone for Helwan Portland Cement Company (HPCC) and National Cement Company (NCC) respectively [12, 13, 15].

Tealeb et al [12, 13] have used three strong motion accelerographs and they have processed and corrected the obtained particle velocity records to achieve the original values of the ground peak particle velocities. They have found that the values of the ground peak particle velocities range from 0.169 to 5.15 cm/sec. Under the city of the 15^{th} of May, two limestone layers were depicted. The upper layer is called weathered limestone layer and the lower layer is called limestone foundation layer. The two layers have a specific gravity of 2.4. Longitudinal and shear wave velocities (Cp and C_S) were available from a previous shallow seismic refraction survey [17]. **Table 4** presents the geographic coordinates of the accelerograph stations, their distances from the quarry and the observed ground peak particle velocities. Equations (9) and (10) were used for calculating modulus of elasticity (E) and equation (11) was used for calculating Poisson’s ratio (υ). Then, equations (2) and (4) were used for strain and stress estimation using P-wave velocities. On the other hand, they used equations (6) and (4) for estimating strains and stresses using S-wave velocities. Their estimated elastic modulus, strain and stress levels for the weathered and foundation layers are presented in **Tables 5** and **6** respectively.

Table 3: Summary of Calculated Normal and Shear Stresses and Strains for Bani Khaled Quarry [4].

Layer 1	Bulk density =2000 Kg/m^3, $C_{p\,max}$ = 1661m/sec , $C_{p\,min}$ = 1612m/sec $C_{s\,max}$ = 1038m/sec , $C_{s\,min}$ = 1003m/sec							
	Peak Particle Velocity from Upper Bench, mm/sec							
	$\mathring{u}_{p\,max}$ = 42.6		$\mathring{u}_{p\,min}$ = 2		$\mathring{u}_{s\,max}$ = 30.4		$\mathring{u}_{s\,min}$ = 1.2	
	σ_{max}, kg/cm^2	ε_{max}, 10^{-6}	σ_{min}, kg/cm^2	ε_{min}, 10^{-6}	τ_{max}, kg/cm^2	γ_{max}, 10^{-6}	τ_{min}, kg/cm^2	γ_{min}, 10^{-6}
	1.44	25.6	0.066	1.24	0.64	29.29	0.025	1.19
	Peak Particle Velocity from Lower Bench, mm/sec							
	$\mathring{u}_{p\,max}$ = 5.8		$\mathring{u}_{p\,min}$ = 1.5		$\mathring{u}_{s\,max}$ = 4		$\mathring{u}_{s\,min}$ = 1.2	
	σ_{max}, kg/cm^2	ε_{max}, 10^{-6}	σ_{min}, kg/cm^2	ε_{min}, 10^{-6}	τ_{max}, kg/cm^2	γ_{max}, 10^{-6}	τ_{min}, kg/cm^2	γ_{min}, 10^{-6}
	1.9	3.5	0.049	0.93	0.085	3.8	0.025	1.19
Layer 2	Bulk density =2200 Kg/m^3, $C_{p\,max}$ = 2838 m/sec , $C_{p\,min}$ = 2480 m/sec $C_{s\,max}$ = 1715 m/sec , $C_{s\,min}$ = 1649 m/sec							
	Peak Particle Velocity from Upper Bench, mm/sec							
	$\mathring{u}_{p\,max}$ = 42.6		$\mathring{u}_{p\,min}$ = 2		$\mathring{u}_{s\,max}$ = 30.4		$\mathring{u}_{s\,min}$ = 1.2	
	σ_{max}, kg/cm^2	ε_{max}, 10^{-6}	σ_{min}, kg/cm^2	ε_{min}, 10^{-6}	τ_{max}, kg/cm^2	γ_{max}, 10^{-6}	τ_{min}, kg/cm^2	γ_{min}, 10^{-6}
	2.71	15.01	0.11	0.806	1.17	17.73	0.044	0.728
	Peak Particle Velocity from Lower Bench, mm/sec							
	$\mathring{u}_{p\,max}$ = 5.8		$\mathring{u}_{p\,min}$ = 1.5		$\mathring{u}_{s\,max}$ = 4		$\mathring{u}_{s\,min}$ = 1.2	
	σ_{max}, kg/cm^2	ε_{max}, 10^{-6}	σ_{min}, kg/cm^2	ε_{min}, 10^{-6}	τ_{max}, kg/cm^2	γ_{max}, 10^{-6}	τ_{min}, kg/cm^2	γ_{min}, 10^{-6}
	0.3697	2.04	0.083	0.605	0.154	2.33	0.044	0.73
Layer 3	Bulk density =2200 Kg/m^3 , $C_{p\,max}$ = 4604 m/sec , $C_{p\,min}$ = 4380 m/sec $C_{s\,max}$ = 3081 m/sec , $C_{s\,min}$ = 2933 m/sec							
	Peak Particle Velocity from Upper Bench, mm/sec							
	$\mathring{u}_{p\,max}$ = 42.6		$\mathring{u}_{p\,min}$ = 2		$\mathring{u}_{s\,max}$ = 30.4		$\mathring{u}_{s\,min}$ = 1.2	
	σ_{max}, kg/cm^2	ε_{max}, 10^{-6}	σ_{min}, kg/cm^2	ε_{min}, 10^{-6}	τ_{max}, kg/cm^2	γ_{max}, 10^{-6}	τ_{min}, kg/cm^2	γ_{min}, 10^{-6}
	4.4	9.25	0.196	0.457	2.1	9.87	0.079	0.41
	Peak Particle Velocity from Lower Bench, mm/sec							
	$\mathring{u}_{p\,max}$ = 5.8		$\mathring{u}_{p\,min}$ = 1.5		$\mathring{u}_{s\,max}$ = 4		$\mathring{u}_{s\,min}$ = 1.2	
	σ_{max}, kg/cm^2	ε_{max}, 10^{-6}	σ_{min}, kg/cm^2	E_{min}, 10^{-6}	τ_{max}, kg/cm^2	γ_{max}, 10^{-6}	τ_{min}, kg/cm^2	γ_{min}, 10^{-6}
	0.60	1.26	0.15	0.34	0.28	1.3	0.079	0.41

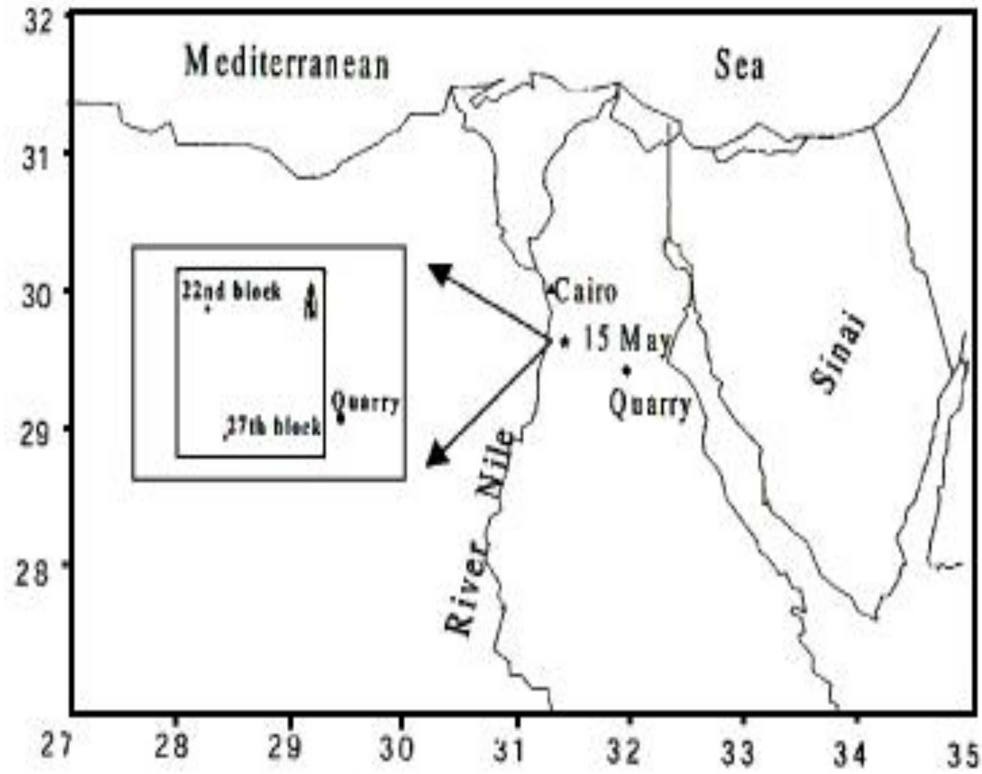

Fig. 2: Location map for the city of the 15th of May and the nearby quarry including a sketch for the observation points.

Table 4: Locations of the accelerographs at the NCC limestone quarry and the 15Th of May Suburbs [12,15].

Station Location	Latitude (N), deg.	Longitude (E), deg.	Distance, km	Maximum **ů,** mm/sec
Quarry Itself	29.816	31.39	0.500	51.5
22nd Suburb	29.831	31.383	2.222	14.94
27th Suburb	29.816	31.380	1.111	43.6

Table 5: Calculated elastic modulus, stresses and strains using longitudinal wave velocity, the 15Th of May Suburbs [12].

Type of layer	C_p, m/sec	**E,** kg/cm^2	Minimum **σ**, kg/cm^2	Maximum **σ**, kg/cm^2	Minimum **ε**, 10^{-6}	Maximum **ε**, 10^{-6}
Weathered	385	3.018E+6	1.324E+5	4.037E+6	4.3896	1.3376
Foundation	952	18.61E+6	3.303E+5	1.006E+7	1.7752	5.4096

Table 6: Calculated elastic modulus, stresses and strains using shear wave velocity, the 15Th of May Suburbs [12].

Type of layer	$C_{s,}$ m/sec	**E,** kg/cm^2	Minimum **σ,** kg/cm^2	Maximum **σ,** kg/cm^2	Minimum **ε**, 10^{-6}	Maximum **ε**, 10^{-6}
Weathered	226	3.04E+6	2.273E+5	6.92E+6	7.4778	2.2787
Foundation	560	18.59E+6	5.613E+4	1.71E+6	3.0178	9.1964

ANALYSES AND DISCUSSIONS

In this section, a comparison will be held between the three case studies.

Analyses and Calculation of Dynamic Strains and Stresses:

In case of Sunlight mine [11] and Bani Khalid quarry [4], stress and strain calculations have been carried out following Dowding's Procedure [2]. Normal strains and stresses have been calculated using equations (2) and (3) respectively. On the other hand, shear strains and stresses have been calculated using equations (6) and (7) respectively. Comparing the results of Sunlight, **Table 1,** to the results of Bani Khalid, **Table 3**, we observe that the distance between the blast and the peak particle velocity (PPV) recording station is 140.2 m at sunlight and ranges from 189 to 311 m at Bani Khalid; the seismic velocities at Sunlight are comparable to the seismic velocities of layer 2, greater than those of layer1, and smaller than those of layer 3 at Bani Khalid; PPV at Sunlight ($\mathring{u}_{pmax}$ = 254 mm/sec) is higher than that at Bani Khalid ($\mathring{u}_{pmax}$ = 42.6 mm/sec from the upper bench) by about six folds. Then, we observe that the stress magnitudes at Sunlight (σ = 16.33 kg/cm^2 and τ = 9.52 kg/cm^2) are higher than that at Bani Khalid (σ_{max} = 2.71 kg/cm^2 and τ_{max}= 1.17 kg/cm^2) more or less by the ratio of PPV. That should be expected because the stresses are proportional to the PPV if the seismic velocities are more or less the same.

Comparing strains at Sunlight (ε = 102 x 10^{-6} and γ = 173 x 10^{-6}) to that of layer 2 at Bani Khalid (ε_{max} = 15.01 x 10^{-6} and γ_{max} = 17.73 x 10^{-6}), we find them proportional to the stresses, i.e. in the case of Sunlight are higher than at Bani Khalid by about the ratio of the stresses. Hence, the magnitude of the stresses and strains at Sunlight and Bani Khalid are compatible.

Comparing Burgher's results of Golden Sunlight mine in **Table 1** and Tealeb et al results of the City of the 15th of May in **Tables 4, 5** and **6**, one observes big difference. Firstly, the distance from the blast to the recording stations at Sunlight mine, 140.2 m, is much smaller than the distances from the blast to the recording stations at the 27th and 22nd Suburbs in the 15th of May City, 1111 and 2222 m respectively. Secondly, the peak particle velocity (PPV) is much greater (254mm/sec) than that at the 27th and 22nd Suburbs (43.6 and 14.94 mm/sec respectively) and 51.5 mm/sec in the quarry itself. This means that the PPV at the Sunlight Mine is higher than the maximum PPV at the 27th suburb by about six times and higher than the PPV at the 22nd suburb by about 17 times, which is logic. Also the seismic velocities at Sunlight are much higher than that at the 15th of May. Hence it is expected to see lower stresses at the 15th of May City than that at the Sunlight Mine. Surprisingly, the stresses at the 15th of May City are greater than that at the Sunlight Mine by the order of 10^5 to 10^6 times. Hence, there is some doubt about the stress calculation procedure in the case of City of the 15th of May. Accordingly, we decided to recalculate the stresses and strains for the case of City of the 15th of May. The results of recalculations of strains and stresses are summarized in **Table 7**.

Table 7: Summary of the re-calculated normal and shear stresses and strains for the weathered layer and the foundation layer, City of the 15th of May

WEATHERED LAYER Bulk density =2400 Kg/m^3, C_p = 385 m/sec, Cs = 226 m/sec.							
Peak Particle Velocity, mm/sec							
$\mathring{u}_{p\ max}$ = 51.5		$\mathring{u}_{p\ min}$ = 1.69		$\mathring{u}_{s\ max}$ = 51.5		$\mathring{u}_{s\ min}$ = 1.69	
σ_{max}, kg/cm^2	ε_{max}, 10^{-6}	σ_{min}, kg/cm^2	ε_{min}, 10^{-6}	τ_{max}, kg/cm^2	γ_{max}, 10^{-6}	τ_{min}, kg/cm^2	γ_{min}, 10^{-6}
0.49	133.77	0.016	4.39	0.28	227.876	0.009	7.478
FOUNDATION LAYER Bulk density =2400 Kg/m^3, C_p = 952 m/sec, Cs = 560 m/sec.							
Peak Particle Velocity, mm/sec							
$\mathring{u}_{p\ max}$ = 51.5		$\mathring{u}_{p\ min}$ = 1.69		$\mathring{u}_{s\ max}$ = 51.5		$\mathring{u}_{s\ min}$ = 1.69	
σ_{max}, kg/cm^2	ε_{max}, 10^{-6}	σ_{min}, kg/cm^2	ε_{min}, 10^{-6}	τ_{max}, kg/cm^2	γ_{max}, 10^{-6}	τ_{min}, kg/cm^2	γ_{min}, 10^{-6}
1.2	54.1	0.0394	1.78	0.706	91.964	0.023	3.017

The newly calculated stress magnitudes for the case of City of the 15th of May have been found much less than that for Sunlight-mine and compatible with Bani Khalid quarry, as they should be. The level of these dynamic stresses is unlikely to cause damage to the buildings of the city. It may cause only some plaster cracking at the most. The minimum normal strains at the City of the 15th of May, **Table 5,** are correct but the maximum magnitudes are not correct. The strains in **Table 6** are "*shear strains"* not *"normal strains"*. The minimum magnitudes in **Table 6** are correct but the maximum magnitudes are not correct. The recalculated correct strains are provided in **Table 7.** The old stress and strain calculations for the City of the 15th of May [12] have been found erroneous. The conclusions based on this study claiming that the damage of the buildings of the city is due to blasting vibrations have to be re-investigated. Damage of the city buildings may be due to other geological, environmental, or even design causes.

Analyses and Calculation of field dynamic elastic constants:

Abdel-Rasoul and Omran [4], in studying the case of Bani Khalid, have calculated the maximum and minimum magnitudes of Poisson's ratio for the three seismic layers using the maximum and minimum magnitudes of C_p and C_s for each layer. The maximum and minimum magnitudes of Young's modulus (E) have been calculated for the three seismic layers using equation (9).

Comparing magnitudes of E in case of Bani Khalid (**Table 2**) to that of the City of the 15th of May (**Tables 5** and **6**), one can see that the magnitudes of E in the case of the 15th of May are higher than those of Bani Khalid by a factor of about 100. This is despite the much higher seismic velocities at Bani Khalid. To confirm the truthfulness of this discrepancy, we have carried out the calculations for Sunlight mine and the 15th of May using the procedure of Abdel-Rasoul and Omran [4] as illustrated above. **Table 8** presents summary of these calculations.

Comparing the magnitudes of E in **Table 8** to that of **Table 2,** one can observe that E magnitudes of Golden Sunlight mine are compatible with that of Bani Khalid quarry because the seismic velocities are compatible too. On the other hand, the newly calculated magnitudes of E for the City of the 15th of May are lower than that for Bani Khalid quarry because the seismic velocities are also lower which makes sense. Indeed, errors in calculating E can lead to errors in stress calculations.

Table 8: Summary of the calculations of the field dynamic Young's modulus for City of the 15th of May and Golden Sunlight mine.

Weathered Layer,15th of May		**Foundation Layer,15th of May**		**Golden Sunlight mine**	
Poisson's Ratio, υ	Young's Modulus, E, 10^4 kg/cm^2	Poisson's Ratio, υ	Young's Modulus, E, 10^4 kg/cm^2	Poisson's Ratio, υ	Young's Modulus, E, 10^4 kg/cm^2
0.237	0.30924	0.235	0.18971	0.235	14.0756

CONCLUSIONS AND RECOMMENDATIONS

Three case studies have been presented and compared. These are Golden Sunlight surface mine (in British Colombia, Canada); Bani Khalid quarry in Samalout, Minia, Egypt and the limestone quarry of the National Cement Company in relation to the City of the 15th of May, Helwan, Egypt. From the results of the performed comparisons, calculations, and analyses some conclusions and recommendations have been drawn:

1- Bani Khalid quarry and Golden Sunlight mine have shown compatible magnitudes of the dynamic Young's modulus, normal stresses and strains.

2- Compared to Bani Khalid quarry and to Golden Sunlight mine, the magnitudes of the dynamic Young's modulus, normal stresses of the city of the 15th of May have been found very high due to erroneous calculations. Hence, re-evaluation of this case has been carried out. The results of the re-evaluation have confirmed much less magnitudes of Young's modulus and normal stresses.

3- The obtained magnitudes of the dynamic Young's modulus, normal stresses and strains for the City of 15th of May are as follows:

i- Poison's ratio is 0.237 for the weathered layer and 0.235 for the foundation layer. They are same as given in the case study.

ii- The dynamic Young's modulus is 3.0924 x 10^3 kg/cm^2 for the weathered layer and is1.8971 x10^4 kg/cm^2 for the foundation layer.

iii- The determined normal strains range from 4.39 x 10^{-6} to 133.766 x 10^{-6} for the weathered layer and from 1.775 x 10^{-6} to 54.096 x 10^{-6} for the foundation layer.

vi- Normal stresses rang from 0.0159 to 0.485 kg/cm^2 for the weathered layer and range from 0.0394 to 1.1995 kg/cm^2 for the foundation layer.

v- The determined shear strains range from 7.47 x 10^{-6} to 227.876 x 10^{-6} for the weathered layer and from 3.017 x 10^{-6} to 91.964 x 10^{-6} for the foundation layer.

iv- The determined shear stresses have a range from 0.0093 to 0.28 kg/cm^2 for the weathered layer and range from 0.0232 to 0.706 kg/cm^2 for the foundation layer.

4- The stress levels of blasting vibrations induced by blasting at the quarries of the National Cement Company are unlikely the cause of the damage of the building in the City of the 15th of May.

5- Reinvestigating the causes of damage to the building in the City of the 15th of May is highly recommended. It may be due to geological, environmental, or even design causes.

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"دراسة مقارنة لتقدير مستوى الاجهادات والانفعالات الديناميكية الناتجة عن اهتزازات التفجير "

تقدير مستوى الاجهادات والانفعالات الديناميكية الناتجة عن الاهتزازات الأرضية بسبب عمليات التفجير في المناجم يهم مهندسي المناجم والمهندسين المدنيين والجيولوجيون. وذلك لما قد تسببه هذه الاجهادات والانفعالات من أضرار للمنشآت المنجمية مثل الحوائط العلوية والفتحات المنجمية أو المنشآت القريبة مثل المباني السكنية والكباري والأنفاق وخطوط الأنابيب ومحطات الطاقة المنشأة تحت الأرض.

تم القيام بهذه الدراسة للتحقق من الادعاءات بأن الاهتزازت اللأرضية الناتجة عن عمليات التفجير في محاجر الشركة القومية للأسمنت قد تسببت في أضرار لمباني مدينة 15 مايو بحلوان. تم عمل دراسة مقارنة بين ثلاث حالات هي منجم جولدن سنلايت السطحي في مونتانا بكندا؛ محجر بني خالد بسمالوط، المنيا؛ ومحجر الشركة القومية للأسمنت وعلاقته بمدينة **15** مايو بحلوان. ونتيجة للدراسة ووجد أن هناك توافقا بين القيم الديناميكية لمعامل ينج والاجهادات والانفعالات الديناميكية في حالة منجم جولدن سنلايت (مونتانا) ومحجر بني خالد. أما حالة مدينة 15 مايو فكانت قيمها مرتفعة جدا مما دعانا الى اعادة حسابها وتقييمها في ضوء حالتي الدراسة الأولى والثانية. وكانت النتائج الجديدة متوافقة في قيمها مع الطريقة الأولى والثانية. وبناءا علي هذه النتائج الجديدة يمكن اعادة النظر في نتائج ومستخلصات الدراسة السابقة لمدينة 15 مايو واعادة تقييم أسباب أخرى لحدوث الأضرار بالمدينة قد تكون جيولوجية أو بيئية أو تصميمية.